E. J. Woodsmall

HERMACH ENGELHARD TRANSFER VOLTAMMETER
MODEL NO. 30081

"A"

INSTRUCTION MANUAL

ENGELHARD

INDUSTRIES, INC.

INDUSTRIAL EQUIPMENT DIVISION
INSTRUMENTS & SYSTEMS SECTION
850 PASSAIC AVE., EAST NEWARK, HARRISON P. O., N. J.

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SAFETY PRECAUTIONS

This instrument, with external accessories, can be operated at potentials which are hazardous. The operator should observe the proper precautions, both for personal safety and protection of equipment.

The metal input terminal marked "G" is connected to the internal shield and should always be grounded.

"Since the thermal converter can be damaged by overloading, the selector switch should be in the rectifier instrument position until the range switch setting has been determined. The selector switch shall be kept in the #2 position between readings."

Caution

The maximum current that can be applied to the thermal converter filament is 7 ma. care should be taken not to exceed this value when checking continuity of same.

METER SPECIFICATIONS

Frequency Range 20 to 50,000 Cps.

Accuracy ± .05% of Full Scale on any Range

RANGE	IMPEDANCE	
15 V	2.000 Ohms	
30 V	4,000 Ohms	
75 V	10,000 Ohms	All ranges 133 Ohms per volt
150 V	20,000 Ohms	
300 V	40,000 Ohms	
5 A	0.1 Ohms	
2.5A	0.2 Ohms	
1.0A	0.5 Ohms	All ranges 0.5 volts drop at
500 MA	1.0 Ohms	rated current
250 MA	2.0 Ohms	
100 MA	5.0 Ohms	

GENERAL DESCRIPTION

The Hermach-Engelhard transfer instrument is a precision A-C multi-range unit with an accuracy of 1/20 of 1% (.05%) through a frequency range from 20 to 50,000 cps. It employs the transfer technique which has been established as standard procedure in making high precision A-C measurements. It does not require a D-C source identical to the rms A-C measured. The circuit design enables power from a small battery to match a large value of alternating current or voltage. The voltage drop in a portion of the D-C circuit is measured with a potentiometer. This potentiometer reading is multiplied by appropriate factors, conveniently located on the range switch to provide the rms A-C measurement.
Basically, the circuit consists of a thermal converter, (Fig. 1), which is shunted to obtain several current ranges, or used in series with appropriate resistors to obtain voltage ranges, (at 133 Ohms per volt).

As shown, (Figs. 2A and 2B) the heater of the thermal converter is switched in series with appropriate resistors, or in parallel with current shunts. The resulting emf of the thermal converter is balanced by an adjustable internal D-C circuit as indicated by the built in galvanometer. The heater is switched to an internal variable D-C source which is adjusted to give the same thermal converter emf and, therefore, the same heater current as the A-C source. The voltage across a portion of this circuit is measured with an external potentiometer. The measured potential is multiplied by a simple factor to obtain the unknown voltage or current. This method of equalizing the D-C produced temperature and the A-C produced temperature eliminates the thermal efficiency factor of the converter, except that it must be stable for at least the duration of the reading and the output must be great enough to obtain the required sensitivity.

The voltage measurement formula is given in Fig. 2A. Please note that the measured A-C voltage depends only on the product of the potentiometer reading and the ratio of the resistance (R_v and R_s).

The current measurement formula is given in Fig. 2B. The value of the measured current is simply the potentiometer reading, divided by the resistance of the four terminal shunt and is independent of the converter temperature vs. resistance characteristic. This is another reason why this instrument is capable of high accuracy.

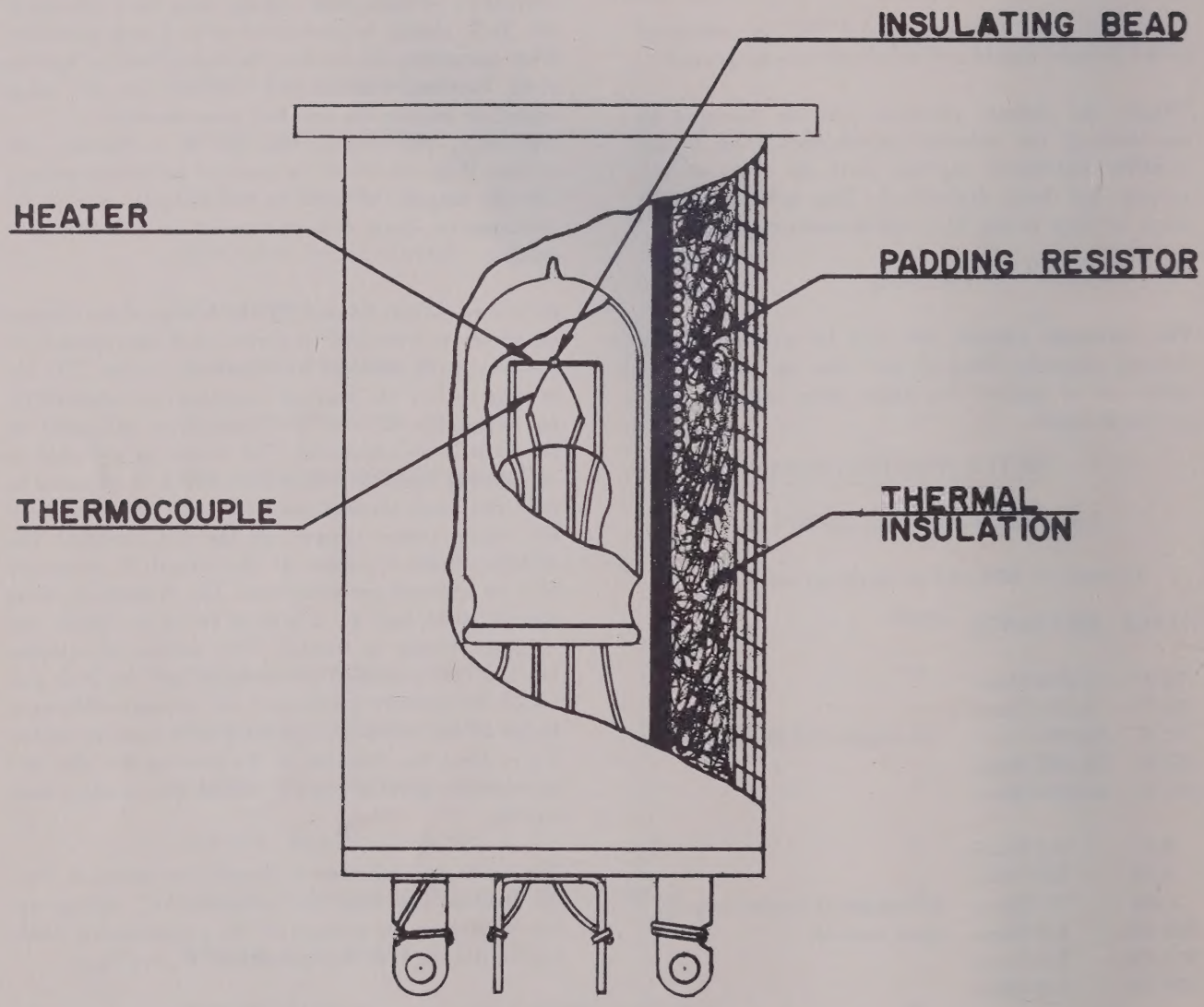
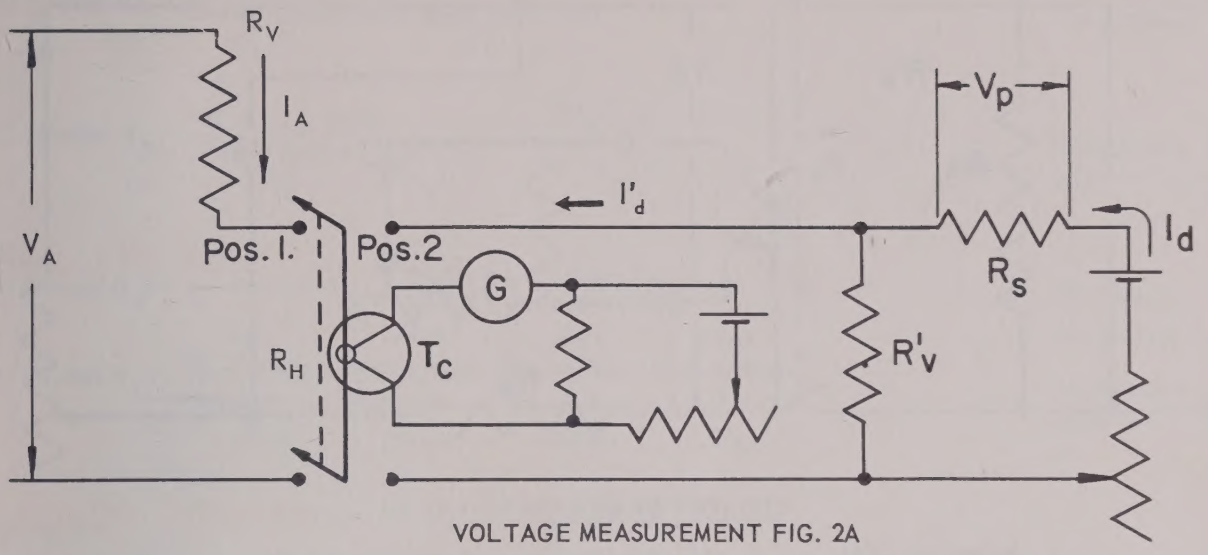


FIG. 1 THERMAL CONVERTER



VOLTAGE MEASUREMENT FIG. 2A

AC voltage (V_A) = AC current (I_A) x [meter resistance (R_V) + heater resistance (R_H)] with switch in Pos. 1

BUT with switch in Pos. 2 at balance

AC current (I_A) = DC heater current (I'd)

DC heater current (I'd) = DC current (I_d) $\times \frac{\text{Compensating resistance } (R'_V)}{\text{Compensating resistance } (R'_V) + \text{heater resistance } (R_H)}$

AC current (I_A) = DC current (I_d) $\times \frac{\text{Compensating resistance } (R'_V)}{\text{Compensating resistance } (R'_V) + \text{heater resistance } (R_H)}$

So AC voltage (V_A) = DC current (I_d) $\times \frac{\text{Compensating resistance } (R'_V)}{\text{Compensating resistance } (R'_V) + \text{heater resistance } (R_H)}$ x meter resistance (R_V) + heater resistance (R_H)

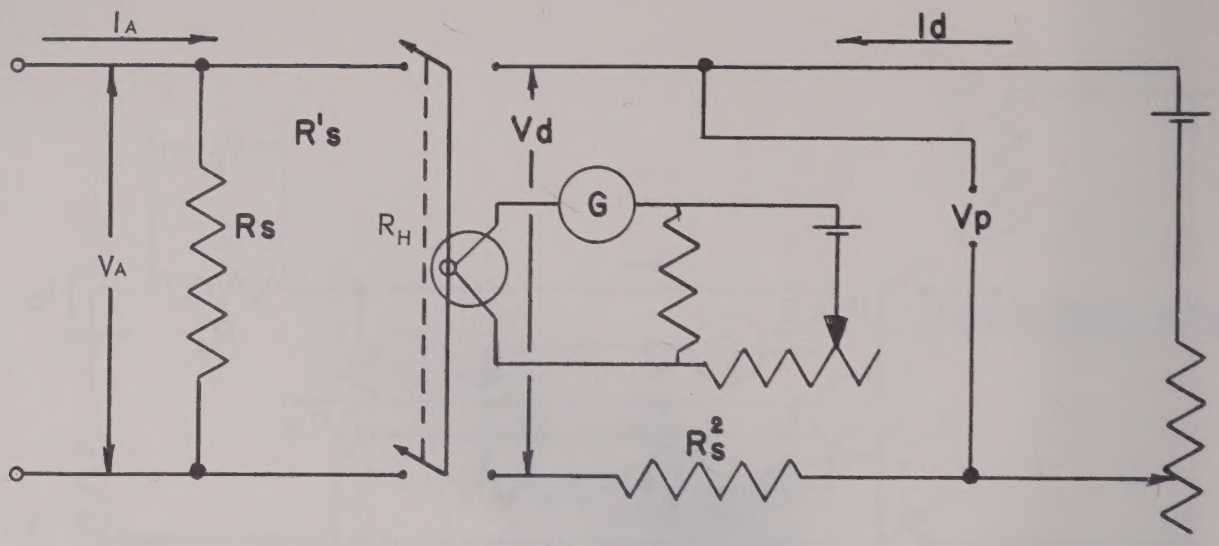
BUT The compensating resistance (R'_V) is equal to the meter resistance (R_V) by design

AC voltage (V_A) = DC current (I_d) $\times \frac{\text{Compensating resistance } (R'_V)}{\text{Compensating resistance } (R'_V) + \text{heater resistance } (R_H)}$ x meter resistance (R_V) + heater resistance (R_H)

AC voltage (V_A) = DC current (I_d) x meter resistance (R_V)

BUT DC current (I_d) = $\frac{\text{Potentiometer voltage } (V_P)}{\text{Precision resistance } (R_S)}$ Ohm's Law

AC voltage (V_A) = Potentiometer voltage (V_P) $\times \frac{\text{Meter resistance } (R_V)}{\text{Precision resistance } (R_S)}$



CURRENT MEASUREMENT FIG. 2B

AC current $(I_A) = \dfrac{\text{AC voltage } (V_A)}{\text{Meter resistance } (R'_S)}$ [R'_S = Combined parallel resistance of the shunt resistance and heater resistance.] — Ohm's Law

BUT

Meter resistance $(R'_S) = \dfrac{\text{Heater Resistance } (R_H) \times \text{shunt resistance } (R_S)}{\text{Heater Resistance } (R_H) + \text{shunt resistance } (R_S)}$ — Formula for total resistance of two resistors in parallel.

AC current $(I_A) = \dfrac{\text{AC voltage } (V_A)}{\dfrac{\text{Heater resistance} \times \text{shunt resistance}}{\text{Heater resistance} + \text{shunt resistance}}}$ — Substitution

AC current $(I_A) = \text{AC voltage } (V_A) \times \dfrac{\text{Heater res. } (R_H) + \text{shunt res. } (R_S)}{\text{Heater res. } (R_H) \times \text{shunt res. } (R_S)}$ — Simplified

BUT

AC voltage (V_A) = DC voltage (V_D)

DC voltage (V_D) = DC current (I_d) x heater resistance (R_H) — Matched through thermal converter to same reference

Therefore

AC voltage (V_A) = DC current (I_d) x heater resistance (R_H) — Substitution

BUT

DC Current $(I_d) = \dfrac{\text{DC Voltage } (V_P)}{\text{Heater Resistance } (R_H) + \text{series resistance } (R^2_S)}$ — Ohm's Law V_P = potentiometer reading

Series Resistance (R^2_S) = shunt resistance (R_S) — By design

Therefore

$$\text{DC Current } (I_d) = \frac{\text{DC voltage } (V_P)}{\text{Heater Resistance } (R_H) + \text{shunt resistance } (R_S)}$$

Subsititution

$$\text{AC voltage } (V_A) = \frac{\text{DC voltage } (V_P)}{\text{Heater Res. } (R_H) + \text{Shunt Res. } (R_S)} \times \frac{(R_H)}{\text{Heater Res.}}$$

Substitution from previous formula

BUT

$$\text{AC Current } (I_A) = \text{AC Voltage } (V_A) \times \frac{\text{Heater Res. + Shunt Res.}}{\text{Heater Res. x Shunt Res.}}$$

Previously determined

$$\text{AC Current } (I_A) = \frac{(V_P)}{\text{DC Voltage}} \times \frac{\cancel{(R_H)}}{\cancel{\text{Heater Res.}}} \times \frac{\cancel{\text{Heater Res. + Shunt Res.}}}{\cancel{\text{Heater Res. x}}\ \text{Shunt Res.}} \times \frac{\cancel{(R_S)}}{\cancel{\text{Heater Res. + Shunt Res.}}}$$

Substitution and simplify

$$\cancel{(R_H)} \qquad \cancel{(R_S)} \qquad \cancel{(R_H)} \qquad (R_S)$$

Therefore

$$\text{AC Current } (I_A) = \frac{\text{DC Voltage } (V_P)}{\text{Shunt Res. } (R_S)}$$

or

$$\text{AC Current} = \text{DC Voltage} \times \frac{1}{\text{Shunt Res.}}$$

The DC voltage is measured by the potentiometer and the reciprocal of the shunt resistance is the meter factor for each current range.

FUNCTIONS OF CONTROLS (Fig. 3)

1. Potentiometer terminals - five ways binding posts; potentiometer leads (shielded) connect to these terminals.

2. Power switch - turns on reference D-C, metered D-C circuits, and galvanometer lamp.

3. Panel (rectifier-type) meter determines optimum setting of range switch, gives initial potentiometer dial setting and also acts as a protective check device to minimize thermal converter damage.

4. Selector switch - selects functions of internal meter circuits.

5. Instruction plate - contains condensed operating instructions and is also a cover plate over the thermal converter, mercury cell pack and lamp battery, allowing easy access to these items.

6. Fine control, metered D-C - makes final adjustment of metered current. Used with optical galvanometer indicator. (Position 2 of selector switch).

7. Course control, metered D-C - used to initially adjust the metered current. Indicated by the galvanometer pointer. (Position 2 of selector switch).

8. Fine control, reference D-C - final adjustment of reference current. Optical indicator. (Position 1 of selector switch).

9. Galvanometer switch - three position spring action switch; normally shorts galvanometer. "Lo" position shunts the galvanometer and "Hi" position gives maximum sensitivity.

10. Galvanometer indicator, optical - light beam indicator used with "Hi" sensitivity position of switch and fine controls.

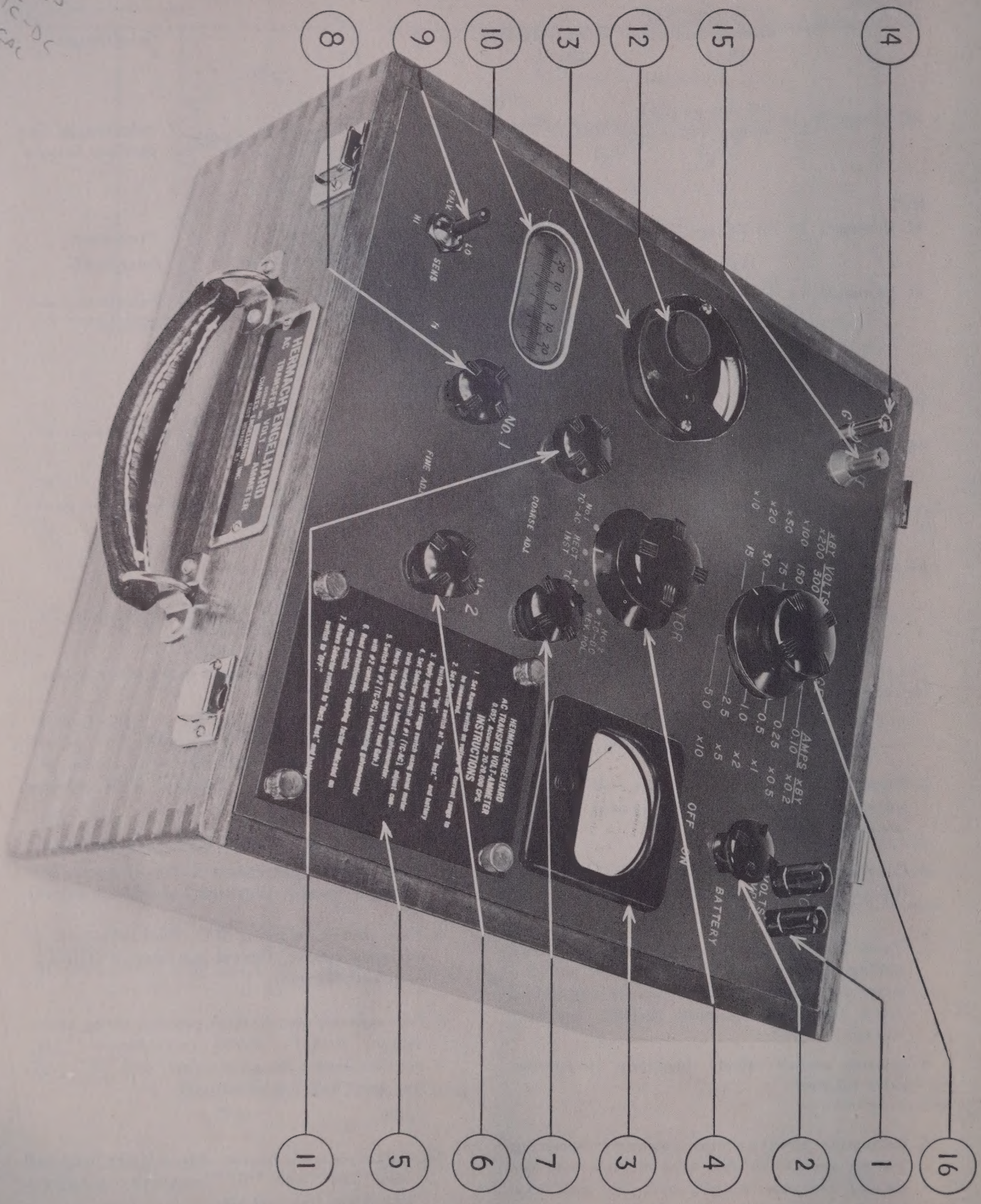


FIG. 3 CONTROL DESIGNATIONS

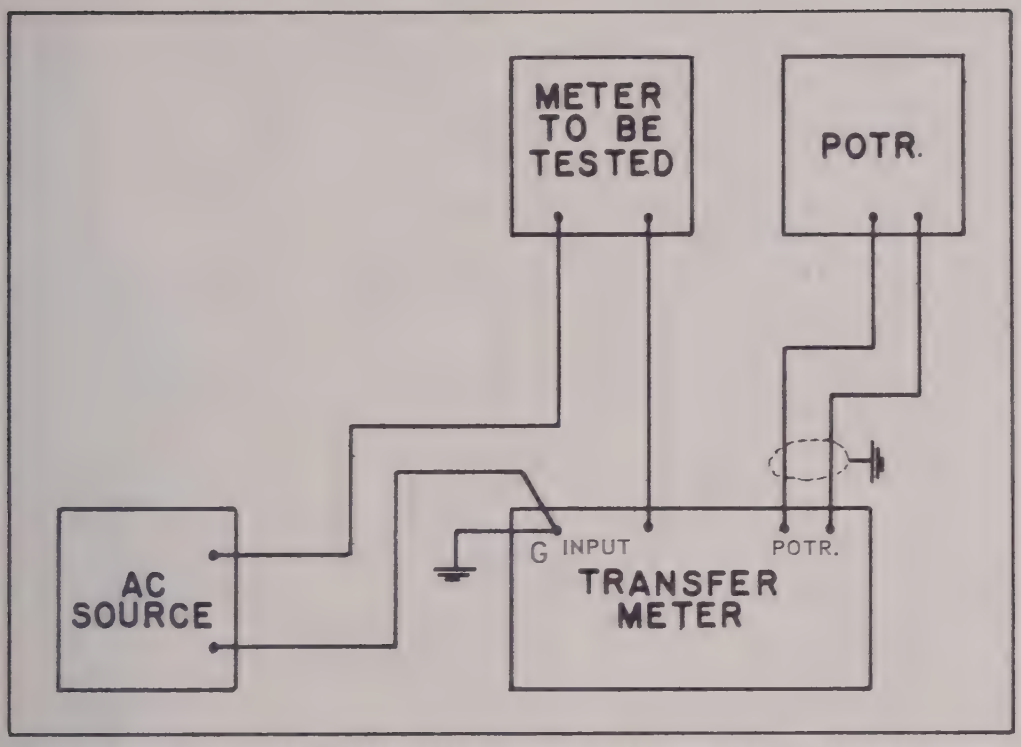


FIG. 4A TYPICAL CIRCUIT FOR CURRENT METER CALIBRATION

11. Coarse control, reference D-C - initial adjustment of reference current. (Position 1 of selector switch).

12. Galvanometer zero adjuster - mechanical control of galvanometer zero current position.

13. Galvanometer indicator, pointer - mechanical indicator has one twelfth (1/12) sensitivity of optical indicator.

14. Ground terminal - input connection. Also meter shield connection. Must be grounded externally.

15. Input terminal - signal is carried to range selector switch from this terminal.

16. Range switch - selects operating range and type of measurement (voltage or current) to be made.

OPERATION

(A) As a measuring instrument.

Connections to transfer instrument should be made according to Fig. 4A or B.

Before applying the A-C power, the selector switch should be placed in the rectifier instrument position and the range switch should be at the maximum range of voltage or current, whichever is to be measured.

Connect a potentiometer having a range of 1.5 volts and an accuracy of 0.015% to the potentiometer terminals (matching polarity markings). Then apply the A-C to be measured to the input terminals. Terminal "G" is connected to the internal shield and should be grounded.

Use the rectifier type panel meter to obtain the correct range: This will prevent the thermal converter from being overloaded. Accurate results will be obtained only with a range setting that gives a meter reading on the upper portion of the scale. Rotate the selector switch to the #1 position and balance the galvanometer with the #1 controls (coarse and fine, 11 and 8 of Fig. 3). This balances the emf developed by the converter. Use the "coarse" control in conjunction with the "Lo" position of the galvanometer sensitivity switch and the "fine" control with the "Hi" sensitivity position.

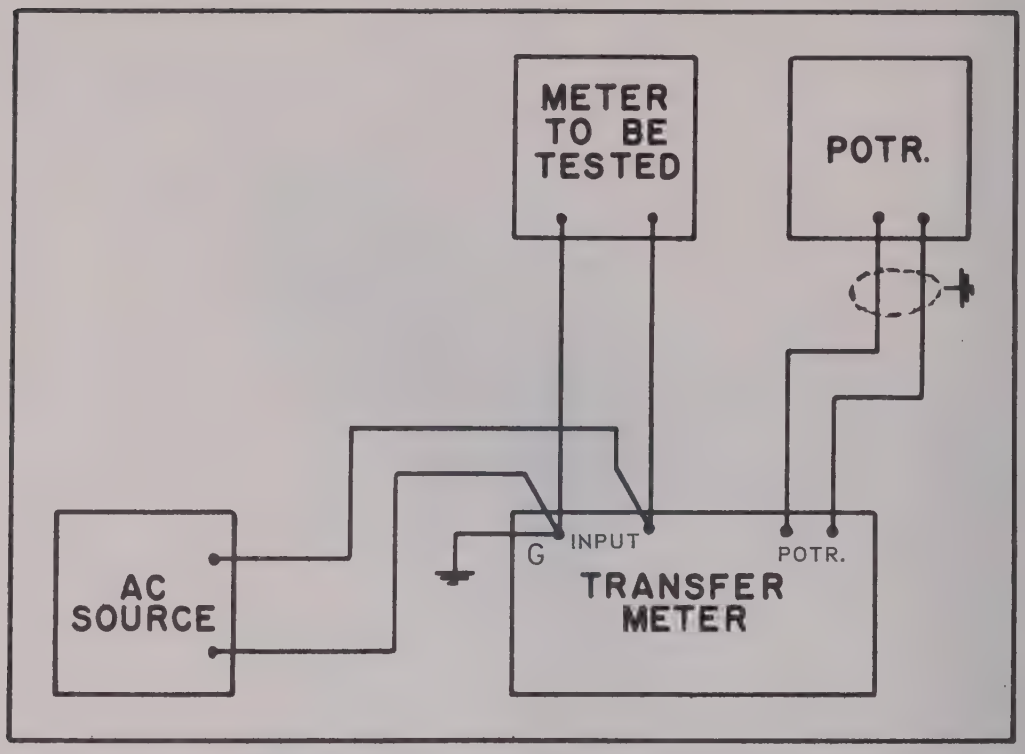


FIG. 4B TYPICAL CIRCUIT FOR VOLTMETER CALIBRATION

Change selector switch to the #2 position and rebalance the galvanometer with #2 controls (7 and 6 of Fig. 3) in the same manner as with the #1 controls. This equilibrates the average D-C and rms A-C values.

When this balance is achieved, balance the potentiometer. The potentiometer reading should be multiplied by the factor indicated on the range switch to obtain actual values. The scale of the panel meter is calibrated in terms of the potentiometer reading (within 5%) and indicates initial setting of the potentiometer dials.

The selector switch shall be kept in the #2 position between readings. After making measurements, the selector switch should be returned to the rectifier instrument position and the battery switch to the off position.

(B) To set a calibration source

Procedure for setting a calibration source can be described by an example, I.E., at 120 volts.

1. Connect the source and external potentiometer to the instrument for normal operation - selector switch in rectifier instrument position.
2. Set range switch while instrument is in this position. This will be the 150 volt range (meter should read 1.2 on voltage scale).
3. Set the precision potentiometer to 1.20000 volts (100 x range equals 120.00 volts).
4. Turn selector switch to No. 2 TC-DC position.
5. Close the test key in the external potentiometer - adjust No. 2 controls until null is obtained on the external galvanometer. This makes the voltage drop across the internal 200 Ohm resistor equal to 1.20000 volts.
6. Press the test key on the Hermach-Engelhard instrument and adjust the No. 1 controls until a null is obtained on the built-in galvanometer. Use maximum sensitivity for final setting. This makes the reference emf equal to the D-C developed emf of the thermal converter.
7. Turn the selector switch to No. 1 TC-AC and, while operating the test key in the Hermach-Engelhard instrument, adjust the external source until a null is obtained. This makes the A-C developed emf of the thermal converter equal to the reference emf.

This procedure should be followed for a few operations to minimize the elapsed time for setup. It is advisable to check the measurement at intervals in the usual way. Manual compensation for slight drift of the power supply can be checked by means of the standard measuring technique.

(C) AC-DC Difference

All thermal converters have small AC-DC differences. This means that if a certain AC current through the converter heater procedes a certain output from the thermocouple, a slightly different amount of DC heater current will produce the same output from the thermo couple.

If the AC-DC difference becomes appreciable the accuracy of the transfer voltammeter will be impaired. The thermal converter used in the transfer voltammeter was specially selected to have a small AC-DC difference. This difference can be checked by noting the value of DC heater current required to produce a certain output from the thermocouple and then reversing the direction of direct current through the heater and again noting the value of DC current required to produce the same output from the thermocouple. The value of alternating current required to produce the same output from the thermocouple lies halfway between the two DC readings, since the alternating current flows one direction half of the time and the other direction for the other half of the time.

In practice the errors due to this difference can be eliminated as follows:

1) Make a measurement of AC voltage or current as previously described, and record the result.
2) Place the selector switch in the No. 2 TC-DC REV. POL. position. This reverses the direction of heater current.
3) Rebalance the galvanometer using the No. 2 controls and again record the result.
4) Average the readings of 1) and 3) above. This will give a more accurate value for the AC voltage or current being measured. If the difference in readings is consistantly more than .03% the thermal converter has a large AC-DC difference and should be replaced.

(D) Erratic Operation

As in all precision slide wire equipment, a certain amount of oxidation can be expected on the slide wire when not in constant use. When the Hermach-Engelhard transfer meter has not been used for a period of time, an erractic or step movement of the galvanometer indicator light may be encountered while adjusting the fine control potentiometers. To insure against this condition which is caused by a film of oxidation, the following procedure is recommended:

With no input applied to the meter terminals, the fine control knobs should be oscillated at least one dozen times in short arcs over the entire range of the potentiometer.

CAUTION

Due to the low impedance of the meter in the voltage ranges (133 Ohms/volts), it would be advisable to leave the meter in the No. 1 position during calibration of the secondary meters unless a thorough check has shown that the rectifier instrument puts the same load on the system as the thermal converter. If the regulation of the power supply is within the necessary limits, then this precaution is not necessary.

ACCESSORIES

A. External voltmeter multiplier

Cased (#30501) with adapter (#32042)

Ranges: 600 and 1200 volts

Accuracy: ± .15%

Frequency range: 20 to 10,000 cps.

OPERATION

Bridge the adapter between the multiplier and voltmeter, inserting the four banana plugs into the corresponding terminals. (Fig. 7).

Connect an A-C source to either the 600 or the 1200 volt terminal and ground terminal on the multiplier.

Follow procedure outlined in operation section (pages 7 and 9); but multiply the potentiometer reading by the factor indicated on multiplier panel adjacent to the terminal used.

B. External ammeter transformer

#30,500 with connections (#30625)

Ranges: 100, 50, 20 and 10 amperes

Frequency range: 25 to 2500 cps.

Each unit supplied with National Bureau of Standards typical response curve and individual transformer data.

OPERATION

Connect transformer to voltmeter, using links (#30625) as shown in Figure 8.

Source is connected to terminals corresponding to the A-C current to be measured.

Set meter range switch at 5 amperes; and proceed according to operating instructions (Page 7).

Current (in amperes) is determined by this formula:

$$I_{A\text{-}C} = F_{POTR.} \times 10 \times \text{transformer range}/5$$

$I_{A\text{-}C}$ = alternating current

$E_{POTR.}$ = potentiometer volts

REPLACEMENT PARTS

Thermal Converter	Part #~~34,288~~ 30,033
Lamp Battery	30,108
Mercury Cell Pack	30,004

When ordering spare parts, please include serial number of the meter.

Determining when a replacement part is needed:

A. Failure of the galvanometer lamp battery is indicated by dimming of the light spot. The "D" size industrial cell is readily obtainable either from Instrument & Systems Division, or local sources.

B. The mercury cell replacement indicator is a rapid steady drift which prevents making a measurement.

C. If a thermal converter has been overloaded but intact, it will be erratic and unstable, even on a battery check, making it difficult or impossible to obtain a galvanometer balance. If the thermal converter is not intact, the trouble will be readily discernible by an inability to balance the galvanometer.

D. The transfer meter can be periodically checked by applying direct current to the input. The D-C value should be determined by a voltbox and potentiometer on voltage ranges and a standard resistor and potentiometer on current ranges. D-C to D-C difference checks should be made by using forward and reverse polarity of the source. This difference should be less than .03% of the scale range.

The D.C. measuring equipment should be certified by the National Bureau of Standards.

REPLACEMENT INSTRUCTIONS

1. Galvanometer lamp battery remove-instruction plate in lower right hand corner. Remove type "D" dry cell; insert new cell and replace cover.

2. Thermal converter - remove instruction plate, pull out converter, slip sleeving back and unsolder 4 leads. Solder leads to new converter, do not use excessive heat, replace sleeving and insert new converter in the instrument. Replace cover.

   Follow color code in soldering leads to terminals.

3. Mercury cell pack - remove instruction plate. Unsolder four (4) leads as shown. Remove pack, insert new pack and solder leads to terminals (following color code). Replace felt block and instruction plate.

The dry cell furnished for the galvanometer lamp is a "leakproof" type. However, if the meter is to be stored or not used for any appreciable length of time, it is advisable to remove this cell from the meter.

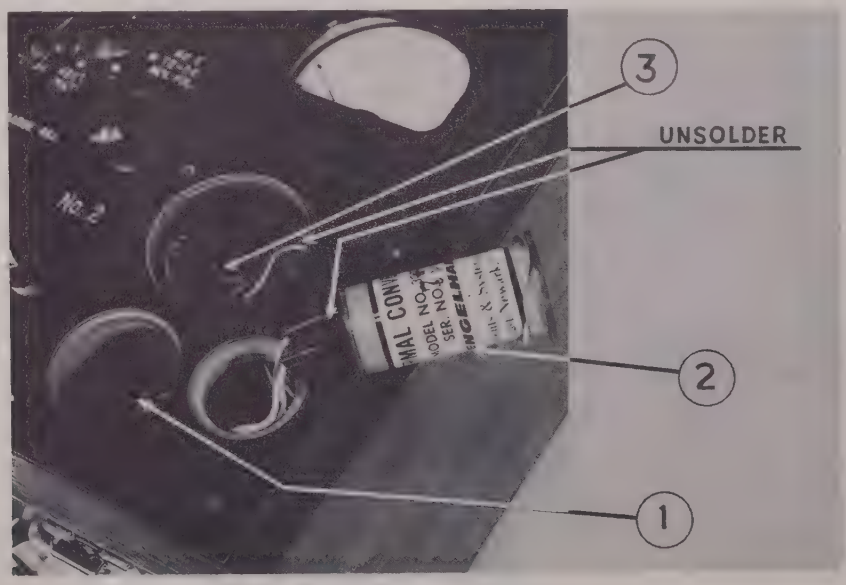


FIG. 5

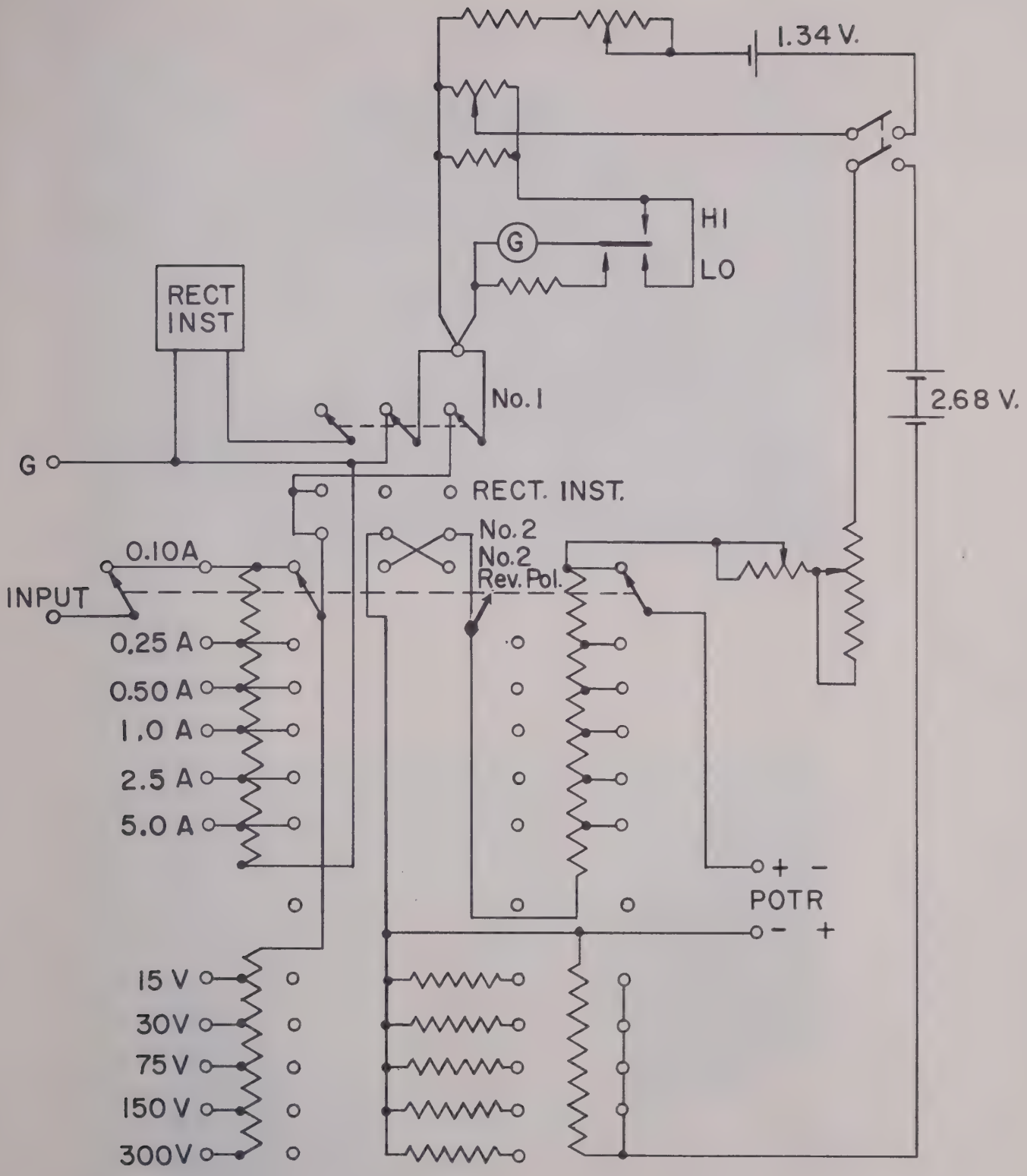


FIG. 6 BASIC SCHEMATIC DIAGRAM

EXTERNAL VOLTAGE MULTIPLIER #30,501

FIG. 7

EXTERNAL AMMETER TRANSFORMER #30,500

FIG. 8

#2300

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